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On *Asperarca* Sacco, 1898 (Bivalvia, Arcidae) and two new Mediterranean species

Rafael La Perna

KEY WORDS: Arcidae, *Asperarca*, Mediterranean, new species, systematics, ecology, prodissoconchs.

ABSTRACT The disregarded genus *Asperarca* Sacco, 1898 is evaluated. Three species occur in the Mediterranean, i.e. *A. nodulosa* Müller, 1776 (originally designated as type-species) and two new species, *A. secreta* and *A. magdalenae*. Both *A. secreta* and *A. magdalenae* are small-sized, the latter being even miniaturized. A lecithotrophic larval development is inferred for *A. nodulosa*, and an intracapsular or brooded one for *A. secreta* and *A. magdalenae*. *Asperarca* has a shelf to bathyal distribution and markedly sciaphilous habits. The hypothesis of a late Tertiary radiation of *Asperarca*, as a temperate or cold-temperate lineage from *Acar*, is proposed.

RIASSUNTO Viene rivalutato il genere *Asperarca* Sacco, 1898, attraverso la descrizione di due nuove specie mediterranee, *Asperarca secreta* e *Asperarca magdalenae*. Specie tipo per designazione originale è *Arca nodulosa* Müller, 1776. *A. secreta* è molto simile ad *A. nodulosa*, e se ne distingue soprattutto per le minori dimensioni, per la scultura più lamellosa e per dimensioni, morfologia e scultura della prodissoconca. Essa è nota per due stazioni della piattaforma profonda del Mediterraneo centrale (Calvi, Isola di Ponza). *A. magdalenae* è una specie miniaturizzata (lunghezza massima 3 mm), e la sua prodissoconca è molto simile a quella di *A. secreta*. E' nota per una grotta oscura della Sicilia sud-orientale a 20 m di profondità, e per due siti pleistocenici a faune superficiali della Sicilia (Capo Milazzo, Grammichele). Lo sviluppo larvale di *A. nodulosa* viene ritenuto di tipo lecitotrofico, e quello di *A. secreta* e *A. magdalenae* di tipo intracapsulare od incubato. *Asperarca* ha nel complesso una distribuzione neritico-batiale in acque temperato-fredde, ed un adattamento marcatamente sciafilo. Viene proposta l'ipotesi che *Asperarca* rappresenti un ramo filetico temperato o temperato-freddo, evolutosi dal *Acar* durante il tardo Terziario.

R. LA PERNA Istituto Policattedra di Oceanologia e Paleoecologia, Università di Catania - Corso Italia 55, I-95129 Catania.

INTRODUCTION

Arca nodulosa Müller 1776 (synonyms *Arca scabra* Poli, 1795, *Arca aspera* Philippi, 1844), a common Northeast Atlantic and Mediterranean arcid, has been generally referred to *Barbatia* Gray 1842 or to *Acar* Gray 1857, the latter often regarded as a subgenus of *Barbatia*. According to the modern systematic views, neither *Acar* nor *Barbatia* offer a suitable allocation for this species, which has been recently referred (OLIVER & ALLEN 1980, OLIVER & VON COSEL 1992a) to *Bentharca* Verrill & Bush 1898 (type-species *Arca asperula* Dall 1881). *Arca nodulosa* is indeed close to *Bentharca asperula* in shell morphology and anatomy (OLIVER & ALLEN 1980). Notwithstanding this, *Arca nodulosa* together with a few poorly-known Miocene species and two small mediterranean species herein described, point to a distinct group, to which the genus name *Asperarca* Sacco 1898 should be applied. *Asperarca* has been disregarded in the past literature on arcids, and NEWELL (1969) synonymized it with *Barbatia*. The systematic and distributional relations of *Asperarca* to other arcid genera are discussed in the present paper.

Systematics

Family Arcidae Lamarck 1818
Subfamily Arcinae Lamarck 1818

Genus *Asperarca* Sacco 1898

Type-species: *Arca nodulosa* Müller 1776, OD Sacco 1898: 10.

Description

Shell equivalve, small, moderately convex. Valve outline subrectangular to subtrapezoidal. Umbo anterior, prosogyrate. Posterior keel well-defined. Sculpture of slightly imbricated concentric lamellae, made crenulate or nodulose by radial riblets, and tending to become raised or projecting on the keel. Dorsal area narrow, expanding with age. Edentulous gap interrupting the tooth series into a shorter anterior set and a longer posterior one. Teeth oblique, in particular the posterior ones. Adductor scars slightly raised. Byssal sinus faint to moderate. Ligament opisthodetic. Periostracum weakly developed.

Remarks

SACCO (1898) reported *Acar* cf. *nodulosa* (Müller) from the Piedmont Miocene ("Elvezian"), describing the "varieties" *subanodosa*, *perelliptica*, *carinatula* and *subelliptica*. Two distinct species can be apparently recognized in "*Acar nodulosa*" and its varieties, the former (pl. II, figs. 19-22) appearing similar to recent specimens of *Asperarca nodulosa* but markedly larger (up to 32 mm in length), and the latter (pl. II, figs. 23-28) recalling the presently described *Asperarca secreta*, but larger (12-13 mm) and more heavily sculptured. From the same area SACCO also reported *Acar aspera* (Philippi) var. *strictula* Sacco from the Piacenzian and *Acar asperella* (Michelotti) from the Tortonian, tentatively regarding *aspera* as distinct from *nodulosa*, and *asperella* as a large Tortonian form of *aspera*. A "topotypic" valve of *Arca aspera* Philippi from the "Pliocene" of Calabria is also reported.

All the illustrated material proves to be in Turin (Museo Regionale di Scienze Naturali) (PAVIA pers. comm.) and a revision will be performed.

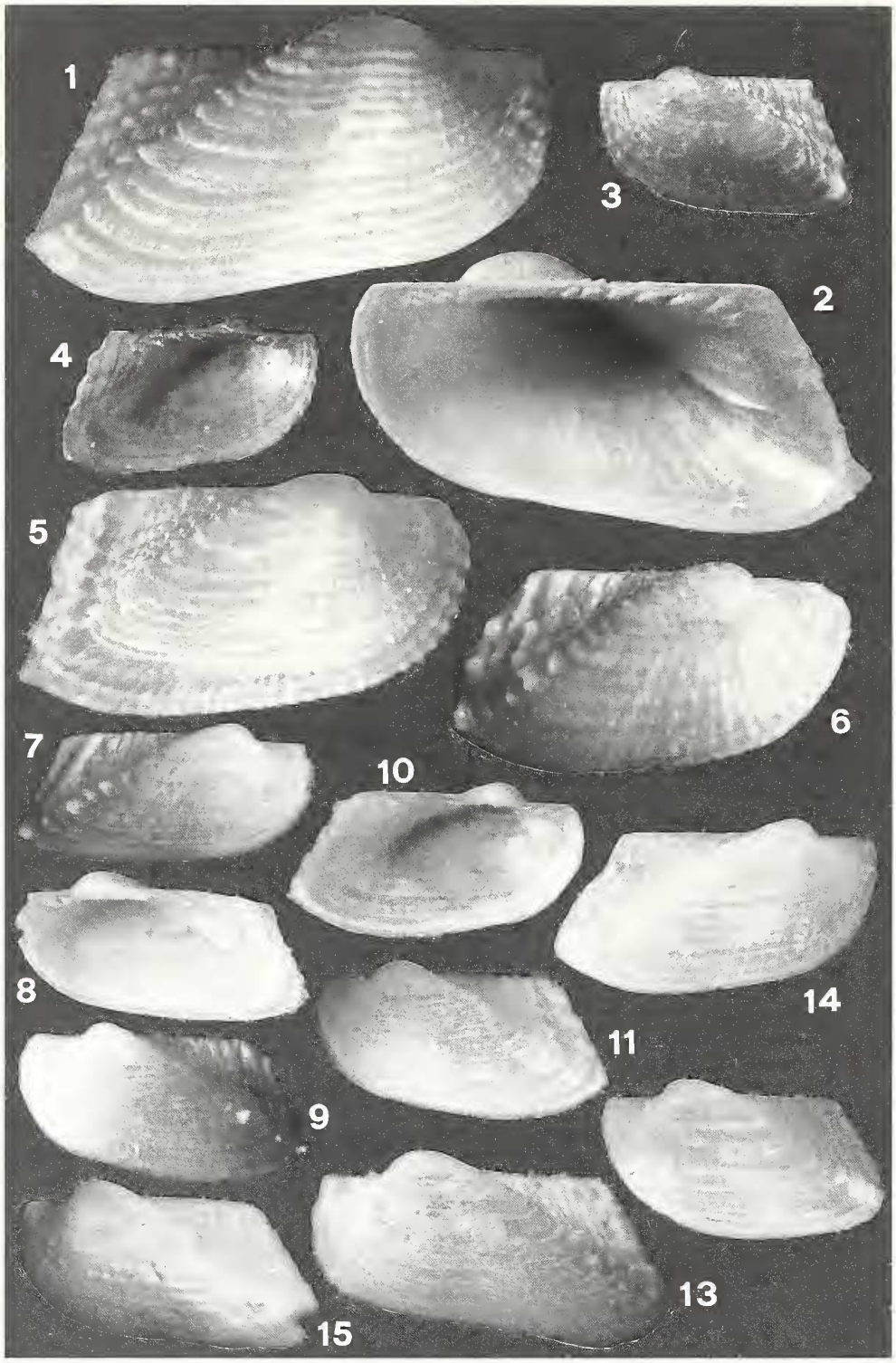

PLATE 1

Fig. 1, 2. *Asperarca secreta* n. sp., holotype, 3.9 mm. Baie de Calvi, 155 m.; Fig.3, 4. *Asperarca secreta*., 2.1 mm. Isola di Ponza, 84 m.; Fig. 5. *Asperarca secreta*, paratype, 3.5 mm.; Fig. 6. *Asperarca secreta*, 3.2 mm. Isola di Ponza.; Fig. 7, 8. *Asperarca magdalenae* n. sp., holotype, 2.5 mm. Gymansium Cave, Penisola della Maddalena (Syracuse, SE Sicily), 20 m.; Fig. 9-13. *Asperarca magdalenae*, paratypes, (9, 10) 2.4 mm, (11) 2.4 mm, (12) 2.3 mm, (13) 3.0 mm.; Fig. 14. *Asperarca magdalenae*, 2.8 mm. Capo Milazzo (NE Sicily), Late Pleistocene.; Fig. 15. *Asperarca magdalenae*, 2.5 mm. Catallarga (Grammichele, SE Sicily), Early Pleistocene.; Size as antero-posterior length.

SACCO remarked a certain closeness of *Arca nodulosa* to *Acar* rather than to *Barbatia*, proposing it as type of a species-group deserving a distinct name, i.e. *Asperarca*. SACCO hesitated in applying this name, as he also noted a closeness to "*Arca profundicola* Verrill" (=*Bentharca asperula*), then referred to *Bathyarca* by DAUTZENBERG & FISCHER (1897).

Taxonomy

Bentharca asperula is the only well-known *Bentharca* species. OLIVER & ALLEN (1980) briefly cited *Bentharca xenophoricola* (Kuroda 1930). It is a Pliocene to Recent Japanese species (see NODA 1988: 116, pl. 1, figs. 13-15) showing more similarity to *Asperarca* than to *Bentharca*.

Bentharca is markedly trapezoidal in shape, with a well-developed posterior part, whereas *Asperarca* is more rectangular or weakly trapezoidal. Some large valves of *A. nodulosa* are strongly expanded posteriorly, but this seems a gerontic feature and/or to be related to the nestling habit. In both genera, a lamellar sculpture occurs, but it is stronger and more heavily decussate in *Asperarca*, whose lamellae become nodulose and somewhat raised, in particular on the keel. *Asperarca* is much more keeled than *Bentharca*, and its adductor scars are raised or ridged, being instead ill-defined in *Bentharca*. The expanding dorsal area and the opisthodetic ligament are shared by *Bentharca* and *Asperarca*. The hinge of *Asperarca* is similar to that of *Bentharca*.

Some shell features shared by *Asperarca* and *Acar* deserve to be noted, i.e. the subrectangular shape, the lamellar and projecting sculpture, the raised adductor scars and the well-defined keel. *Acar* has a markedly foliate juvenile sculpture, becoming strongly vesicular or tile-like with growth, and contrasting with the much weaker sculpture of *Asperarca*. It should be noted that oblique posterior teeth and edentulous gap also occur in juvenile valves of *Acar* and *Barbatia*, the gap becoming lost in fully grown valves. *Barbatia* is characterized by a more equilateral and weakly keeled shell, lacking any lamellar sculpture and with somewhat serrate and almost vertical teeth in adult valves.

Asperarca secreta n. sp.

Pl. 1, Figs. 1-6; Pl. 2, Figs. 5-10; Pl. 3, Figs. 3, 4

Type material

Holotype: a right valve. Paratypes: over 970 loose valves. Paleontological Museum of Catania University (I.P.O.P.).

Type locality

Baie de Calvi (Corsica), 42°36'00"N/8°39'07"E, 155 m.

Material examined

The type material and 12 loose valves from Isola di Ponza (Central-Eastern Tyrrhenian), 40°52'14"N/12°55'51"E, 84 m.

Description

Shell small, moderately thick. Outline subrectangular to slightly trapezoidal. Dorsal margin long, straight. Ventral margin gently sloping to almost straight, faintly sinuosus. Anterior margin curving into the ventral one. Posterior margin gently sloping, generally frilled. Postero-ventral junction subacute to rounded. Umbo anterior, prosogyrate. Posterior keel well-defined. Concentric scultpure of slightly imbricated lamellae, becoming shortly projecting on the keel, and radially nodulose on the postero-dorsal area. Radial riblets making the lamellae crenulate to nodulose. Hinge-plate moderately thin, with a wide endentulous gap. Three short anterior and six oblique posterior teeth in the holotype. Dorsal area narrow, becoming wider in gerontic specimens. Adductor scars unequal, faintly ridged, the posterior slightly larger than the anterior one. Byssus retractor scar elongate, almost as long as the posterior tooth row. Prodissoconch D-shaped, 270-320 µm in length, 220-240 µm in heigth, pitted at optical magnification and foveolate at SEM.

Colour cream with darker radial bands, to evenly light brown. Holotype 3.7 mm in length, 2.2 mm in height, 0.8 mm in tumidity. Maximum shell length 3.9 mm.

Etymology

From the Latin *secretus* (=secret, hidden), this species having been overlooked probably because of its similarity to small specimens of *A. nodulosa*.

Remarks

A. secreta might be misidentified as small specimens of *A. nodulosa*. The latter is larger (up to ca. 15 mm in length) and when of the same size, the former differs in being more convex, more rectangular, more acutely keeled and with a larger umbo. In *A. secreta* the edentulous gap is wider, the posterior teeth fewer, the sculpture more lamellar and less decussate than in *A. nodulosa*.

The keel sculpture is only weakly raised in *A. nodulosa*, whereas it is projecting in *A. secreta*.. The prodissoconch of *A. secreta* is D-shaped and matt, being smaller, roundish and polished in *A. nodulosa*. Small valves of *Barbatia barbata* (Linnè 1758) are quite distinct, being flatter, almost unkeeled, finely decussate and lacking any raising sculpture.

Variability mainly involves the valve outline (more or less trapezoidal) and the keel sculpture (fluted to slightly foliate or vesicular). Shell deformations are frequent.

Distribution

Recent, Central Mediterranean.

Asperarca magdalenae n. sp.

Pl. 1, Figs. 7-15; Pl. 3, Figs. 1, 2;

Type material

Holotype: a right valve. Paratypes: over 800 valves. Paleontological Museum of Catania University (I.P.O.P.).

Type locality

Penisola della Maddalena (Syracuse, southeast Sicily), inside the Gymnasium Cave, 37°00'20"N/15°18'80"E, 20 m.

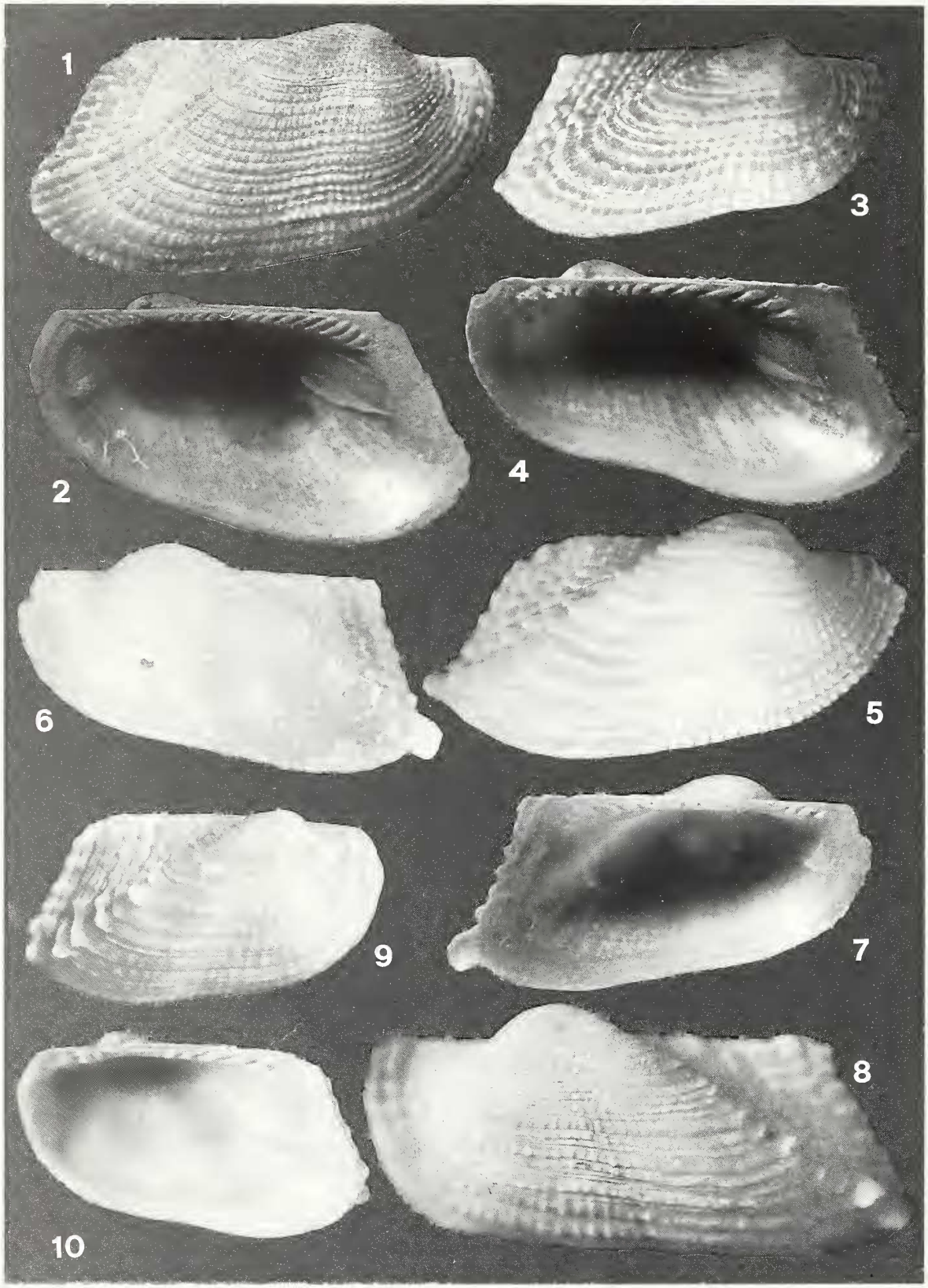

PLATE 2

Fig. 1-4. *Asperarca nodulosa* (Müller), (1) 9.3 mm, (2) 9.1 mm, (3) 3.8 mm, (4) 4.3 mm. Baie de Calvi, 155 m.; Fig. 5-8. *Asperarca secreta*, paratypes, (5) 4.7 mm, (6, 7) 4.0 mm, (8) 5.4 mm.; Fig. 9, 10. *Asperarca secreta*, 3.7 mm. Isola di Ponza.; Size as antero-posterior length.

Material examined

The type material, coming from a bottom sample and consisting of empty shells (mostly as loose valves). One left valve from Catallarga (Grammichele, southeast Sicily; Early Pleistocene). Two right valves and a left one from Capo Milazzo (Messina, northeast Sicily; Late Pleistocene).

Description

Shell markedly small, thin, semitransparent, somewhat shining and convex. Outline subrectangular to slightly trapezoidal. Dorsal margin long, straight. Ventral margin gently sloping, slightly convex to almost straight, sometimes faintly sinuosus.

Posterior margin straight, sloping, slightly frilled, subacutely joining the ventral one. Anterior margin curving into the ventral one. Umbo markedly anterior, prosogyrate. Keel somewhat acute. Dotsal area narrow, becoming widet in geróntic specimens. Concentric scultpure of sligthtly imbricated lamellae, becoming shortly projecting on the keel and weakly nodulose on the postero-dorsal area. Thin radial wide-spaced riblets, slightly crenulating the lamellae. Hinge-plate thin, with a wide endentulous gap. Three short anterior and five elongate oblique posterior teeth in the holotype. Byssal gape very narrow. Adductor scars unequal, faintly ridged, the posterior larger than the anterior one. Byssus retractor scar elongate, almost as long as the posterior tooth row. Prodissoconch D-shaped, 270-330 µm in length, 200-230 µm in heigth, pitted at optical magnification, foveolate at SEM. Colour withish to cream, often radially caramel tinged.

Holotype 2.5 mm in length, 1.3 mm in height, 0.6 mm in tumidity. Maximum shell length 3.0 mm.

Etymology

From the latinized name of the type-locality Peninsula, *Magdalena*.

Remarks

A. magdalenae can be easily misidentified as a very young arcid stage but, except for *A. secreta*, none of the Mediterranean species has a young stage resembling it, neither in shell morphology, nor in prodissoconch shape, size and sculpture.

The present species can be distinguished from *A. secreta* in being smaller, thinner (semitransparent), more convex, more acutely keeled and weakly scuptured.

Variability mainly involves the outline (more ot less trapezoidal). The keel sculpture may be fluted to slightly foliate or vesicular.

Distribution

Pleistocene to Recent, Sicily.

Ecology and distribution

A. nodulosa ranges from subarctic to mid Northeast Atlantic latitudes, undergoing a southward immersion from shelf (10-20 m) to 3,000 m (Oliver & Allen 1980, Oliver & Von Cosel 1992a). In the Mediterranean, it has a deep-shelf (from ca. 100 m) to bathyal distribution. It is also very common in the Pleistocene bathyal deposits of Southern Italy, from which it has been reported as *Acar* or *Barbatia scabra* (Di Geronimo 1979, La Perna 1994, Barrier *et al.* 1996).

A. secreta is a deep-shelf species, probably spreading into upper bathyal depths. Both it and *A. nodulosa* occurred abundantly in the Calvi station (155 m), from coarse-grained bottoms colonized by *Gryphus vitreus* communities (Di Geronimo *et al.* 1977, Falconetti 1980). Few valves of *A. secreta* were found in the Ponza station (84 m), characterized by an abundant coarse biogenic fraction (coralline algae and bryozoans).

Judging from its abundance as empty shells in the bottom sample, *A. magdalenae* is the most abundant mollusc species in the Gymnasium Cave. It is a carstic cave, ca. 60 m long and blindly ending (morphology and topography reported by Leonardi 1994). In the sampled site, ca. 40 m from the opening, the cave is "Dark" (*sensu* Pérès & Picard 1964, Harmelin *et al.* 1985). The sediment is muddy and the dead arcids on the bottom must be assumed have fallen down from the surrounding walls.

The fossil findings of *A. magdalenae* agree with a shallow-water distribution. The mollusc assemblage from Capo Milazzo is referable to an infralittoral sandy bottom, sheltered by a *Posidonia* "récif barrière" (see Pérès & Picard 1964: 55), from which many mollusc shells became displaced to the sandy bottom.

Malacofaunistic observations from this bed, representing the strato-type of the Milazzian stage (Late Pleistocene), were reported by Ruggieri & Greco (1965). The Milazzian stage is now assumed as corresponding to the warm Tyrrhenian stage (Pasini & Vai 1996). The depositional paleobiotope of Catallarga is referred to a infra-circalittoral coarse bottom, swept by currents and "collecting" biogenic clasts from the surrounding areas (La Perna in press a). The age is Early Pleistocene.

The sciaphilous habit is an outstanding ecological feature of *Asperarca*. This is particularly obvious for the shallow-water *magdalenae*, as pointed by its abundance in a dark cave. The deep-shelf distribution of *A. secreta* and the deepening one of *A. nodulosa* also fit this hypothesis. A cryptic habit, within crevices, *Posidonia* rizhomes and algal beds can be also inferred for *A. magdalenae*. Sciaphilous adaptations seem widespread among arcids, often co-occurring with nestling habits. The shallow-water *Acar pulchella* is frequently reported for Mediterranean cave communities (Cattaneo & Russo 1987, Balduzzi *et al.* 1989, Di Geronimo *et al.* 1997).

The geographic and bathymetric distribution of *A. nodulosa* points to a cold-temperate and eurybathic adaptation, rather than a true deep-sea one. In this, the ecology of *A. nodulosa* is markedly different from that of *Bentharca aspera*, a cold-water and deep-sea species, which is absent from the Mediterranean despite its world-wide distribution (Knudsen 1970). The cold to temperate range of *Asperarca* is also different from that of *Acar* and *Barbatia*, which are mainly restricted to shelf and warm waters, showing a maximum diversity in the Caribbean, Indo-Pacific and Panamic provinces (Oliver & Von Cosel 1992b). It is also worth noting that the temperate geographic distribution of "*Bentharca*" *xenophoricola*, and the bathymetric one (50-500 m, Noda, 1988: 113), agree with the ecological range of *Asperarca*.

Prodissoconch morphology

In terms of the arcid size range, *A. secreta* and *A. magdalenae* appear as small species, the latter being even miniaturized and, probably, the smallest arcid so far known.

The peculiar prodissoconch morphology of both species is probably related to their small size. Two prodissoconch types can be recognized among the Mediterranean arcids. In the first type (e.g. *Arca tetragona*), the larval shell is clearly demarcated into prodissonch I and II, typically indicating a planktotrophic development. *A. nodulosa* (Pl. 3, Fig. 5) (as well as *Barbatia barbata* and *Acar pulchella*) have ovate-roundish and polished prodissoconchs, with a weakly developed prodissoconch II, and a somewhat pointed apex. The larval shell of *A. secreta* and *A. magdalenae* (Pl. 3, Figs. 1-4) is markedly different from both these types, being larger, D-shaped, matt and somewhat raised from the surrounding shell. At SEM it is densely foveolate, with a smoother marginal rim and a stepped metamorphic line. A prominent apex also occurs in these larval shells. The large, D-shaped, pitted and stepped prodissoconch reported by OLIVER & CHESNEY (1994) for a rather small Arabian *Acar* seems to be closely comparable to this morphological type. The unusual cap-shaped prodissoconch reported by KILBURN (1983) for a South African *Acar* is also worth of being mentioned.

A planktotrophic development is generally known for arcids (e.g. JØRGENSEN 1946, JABLONSKI & LUTZ 1983), but the widespread occurrence of non-planktotrophic development should be also acknowledged. KNUDSEN (1970, 1979), suggested a lecitrophic development in *Bentharca asperula* on account of egg and prodissoconch size and KILBURN (1983) reported a brooding habit in a South African *Barbatia (Calloarca)* species (whose prodissoconch was said "flatly domed, ill-defined"). According to OCKELMANN's observations (1965), the second type here described should be referred to a lecitotrophic development with a short planktonic stage. Conversely, the prodissoconch of *A. secreta* and *A. magdalenae* might be refererred to a "direct" development (more correctly "intracapsular", BOUCHET 1989), taking place into the egg. A brood-protection can be also expected for these species. A body size reduction implies a lowering in fecundity and a shifting from r- to K-strategy, owing to the decreased energy and body volume suitable for egg production (JABLONSKI & LUTZ 1980, 1983; HANKEN & WAKE 1993). In this regard, it is worth remarking that the miniaturized nuculoid *Microgloma pusilla* (Jeffreys) (ca. 1 mm) broods a single young at a time (OCKELMANN & WARÉN in press), whereas a short free lecitotrophic development is typically known for standard-sized nuculoids.

The shifting from planktotrophy to non-planktotrophy is probably more widespread among Arcacea than so far known, and the occurrence of sibling species differing in the larval development (as well-known for gastropods: e.g. LA PERNA 1997), should be expected. OLIVER & ALLEN (1980) reported two prodissoconch sizes in deep-sea Northeast Atlantic populations of *"Bentharca nodulosa"*. They observed no other anatomical, morphological or distributional differences, concluding that two developmental types (lecitotrophic and direct) or different larval stage durations occur in the same species.

Concluding remarks

The present study leads to a more composite systematic and evolutionary view of the European arcids. *Asperarca* seemingly radiated during the late Tertiary and some morphological and ecological features may lead to see *Asperarca* as a temperate-cold lineage from *Acar*. The deep-sea radiation of *Bentharca* from *Asperarca* may be also a working hypothesis. The apparently close Western Pacific *"Bentharca" xenophoricola* may indicate a disjunction in the original distribution of *Asperarca*, due to the suppression of Mesogea, as recently remarked for the nuculoid genus *Jupiteria* (LA PERNA in press, b).

Due to its wide and temperate to cold thermal range, as well as to its sciaphily, *Asperarca* is able to spread well beyond the shelf, without being, however, a deep-sea genus. Further, body size reduction might be seen as an adaptive trend to cryptic habits.

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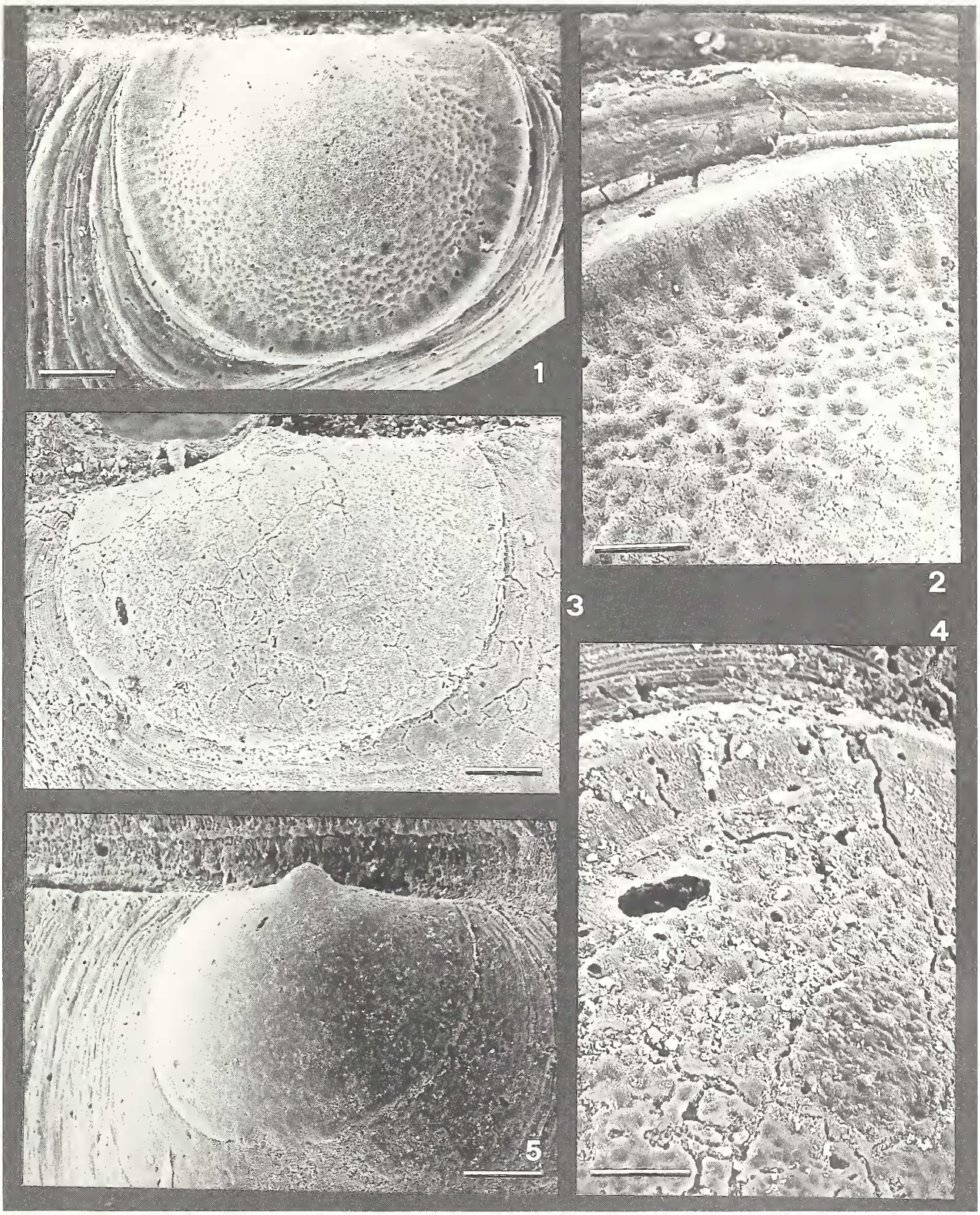

PLATE 3

Fig. 1, 2 - *Asperarca magdalenae*. Prodissoconch: general view (1) and detail of a marginal area (2). Scale bars = 50 µm (1) and 20 µm (2). Fig. 3, 4 - *Asperarca secreta*. Prodissoconch: general view (3) and detail of a marginal area (4). Scale bars = 50 µm (3) and 20 µm (4). Fig. 5 - *Asperarca nodulosa*. Prodissoconch. Scale bar = 50 µm.

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